Seismic Sustainability Assessment of Structural Systems: A Preliminary Case Study

Trevor Z. Yeow, Gregory A. MacRae,
Rajesh P. Dhakal and Brendon A. Bradley

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

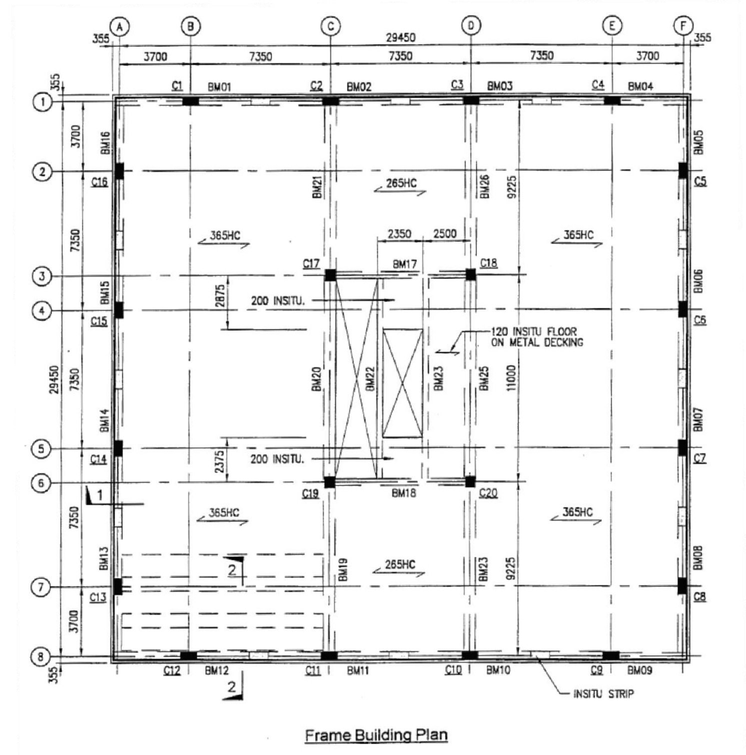
INTRODUCTION

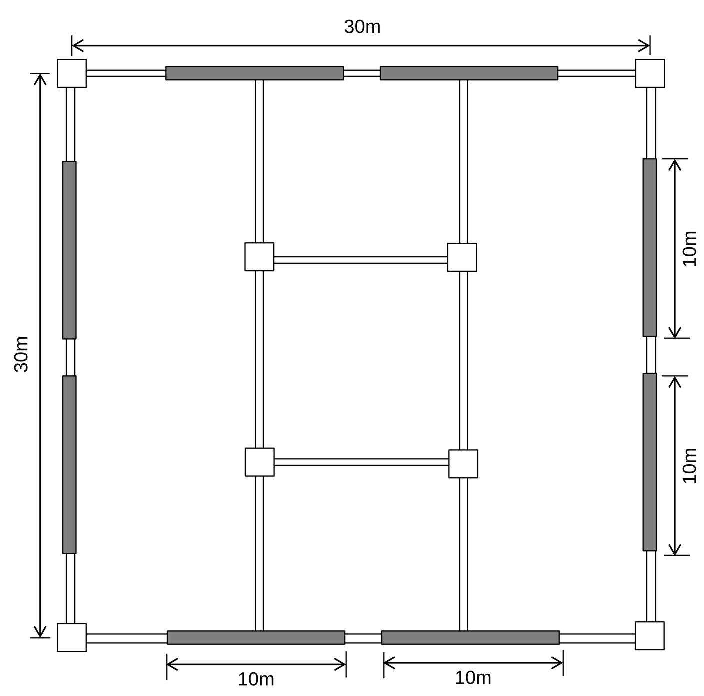
The University of Canterbury has initialized a research program focusing on the seismic sustainability of structures. As part of this program, the relative seismic sustainability of various structures will be assessed to identify those with the highest sustainability for the Christchurch rebuild and general use in New Zealand.

This preliminary case study assesses one reinforced concrete (RC) frame structure and one RC wall structure. The scenario loss is evaluated for two earthquake records considering direct losses only in order to explain and illustrate the methodology.

STRUCTURE AND EARTHQUAKE RECORDS

The frame structure considered in this study is the Red Book building (Bull et al, 2006). This 10-storey building was designed according to NZS 1170.5:2004 and NZS 3101:2006 with a design global ductility of 4. An equivalent wall structure of similar dimensions was designed to the same standards and design ductility. Structural analyses were conducted using Ruaumoko2D.





For this study, the structures were assumed to be located near the Botanical Gardens in Christchurch. Ground motions recorded at the Botanical Gardens during the Darfield earthquake (04/09/2010) shaking and the more intense Christchurch earthquake (22/02/2011) shaking were used .

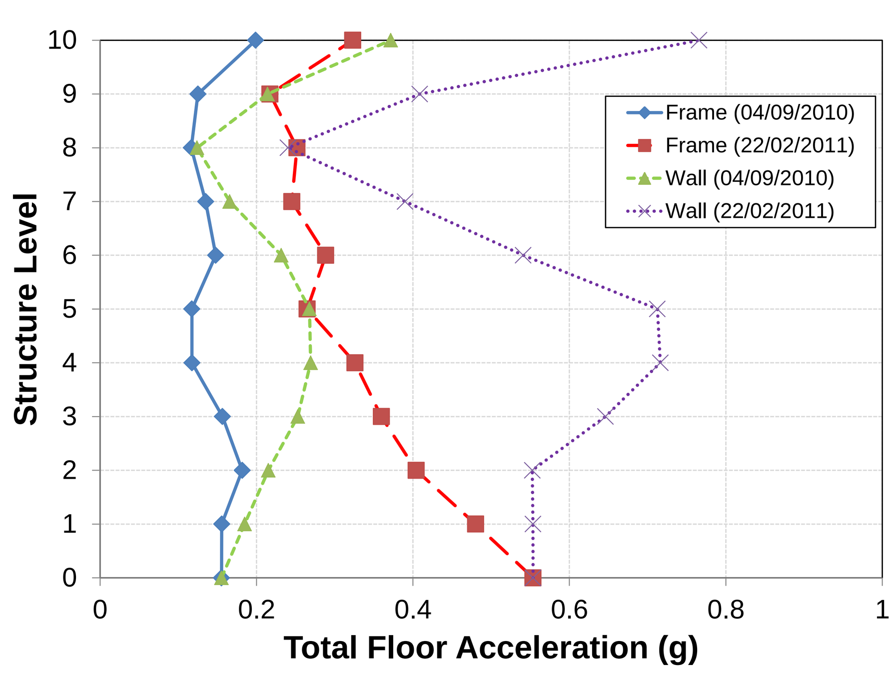
The building contents used in this study were based on Bradley et al (2009). It was assumed that the non-structural content of both structures were the same, and the only difference in the initial cost was in the cost of the structural components. In this case study, the wall structure cost approximately $300,000 more than the frame structure (increase of 2.7% of the frame structure cost). Loss assessments were conducted using the Seismic Loss Assessment Tool, SLAT, a computer program developed at the University of Canterbury.

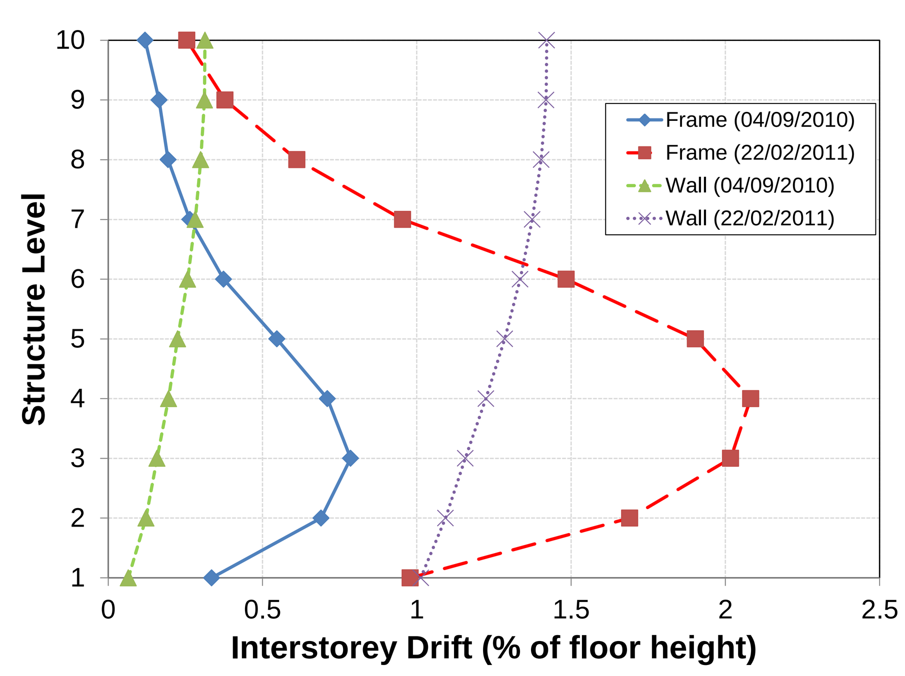
STRUCTURE RESPONSE

The acceleration and interstorey drift profiles of the RC structures from the structure analyses are shown in the figures below.

From the total floor acceleration profiles for the different earthquakes, it can be seen that the wall structure generally has higher floor accelerations than the frame structure for the particular records used. This is because the wall structure was much stiffer than the frame structure. Also, the highest accelerations occur at the top level for the wall structures.

From the interstorey drift profiles, the frame structure has larger interstorey drifts over the bottom half of the structure, and smaller drifts towards the top of the structure. However, in the wall structure the interstorey drift increases with floor height. This can be linked to the mode of deformation of the two different structures.

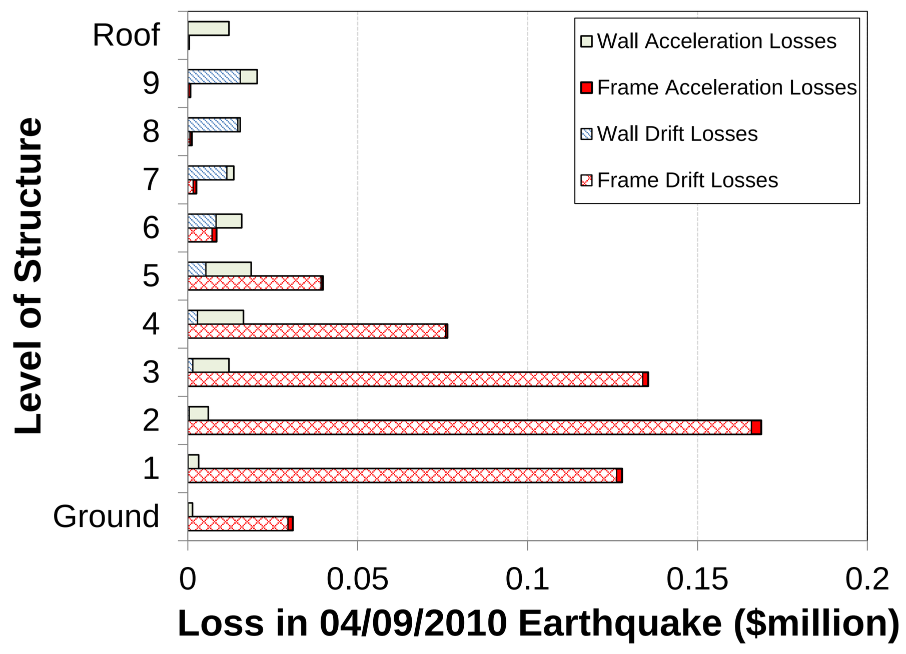


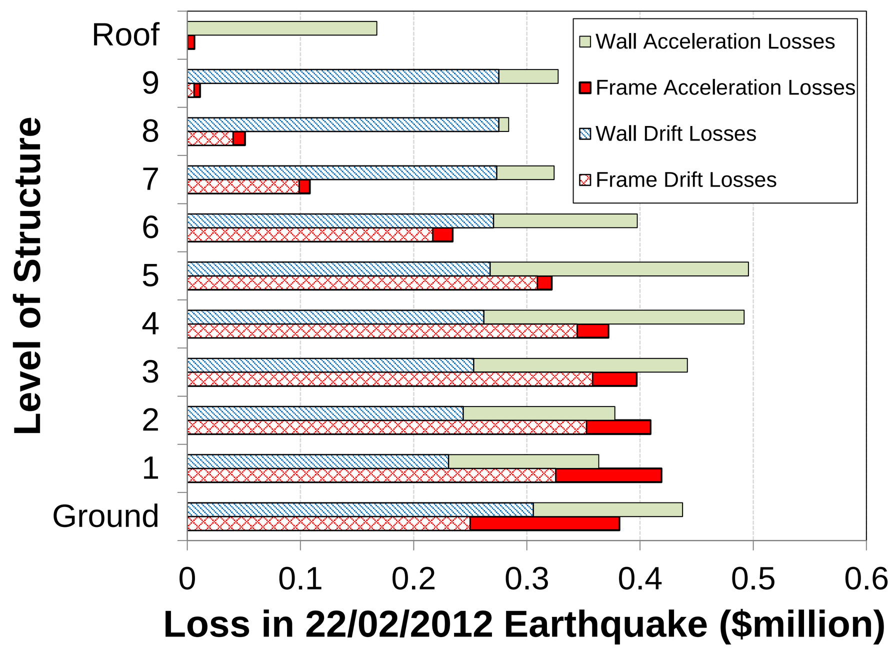


STRUCTURE LEVEL LOSSES

The figures below show the losses at each level of the structure. In both earthquake events, losses resulting from drift dominate the frame losses. The drift losses are less significant towards the top of the frame structure.

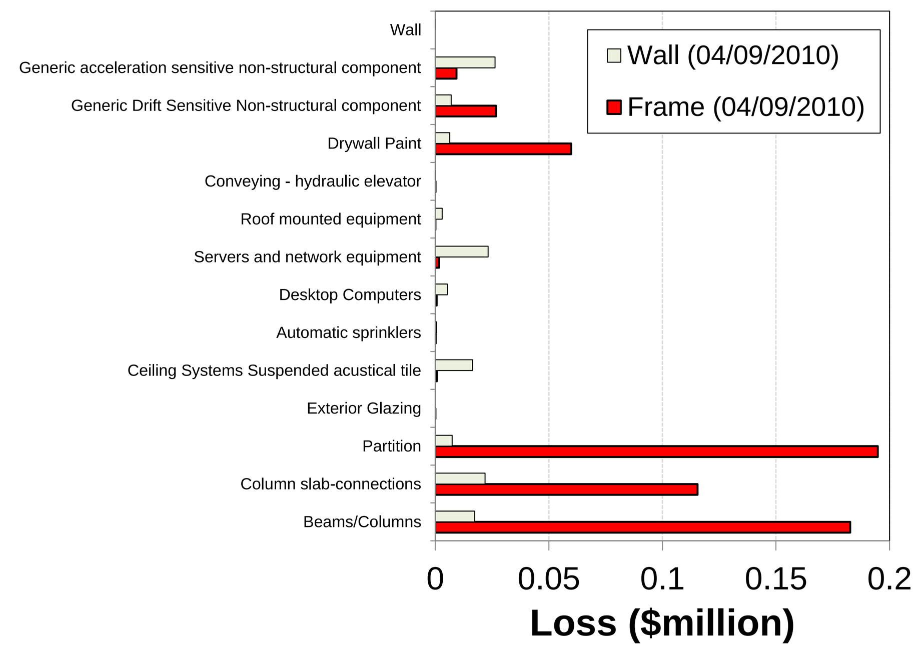
The wall structure performed well in the 04/09/2010 event. In the 22/02/2011 event however, there were significantly more losses resulting from both drift (particularly the top few storeys) and acceleration than for the frame structure. This can be linked back to the acceleration and interstorey drift profiles.

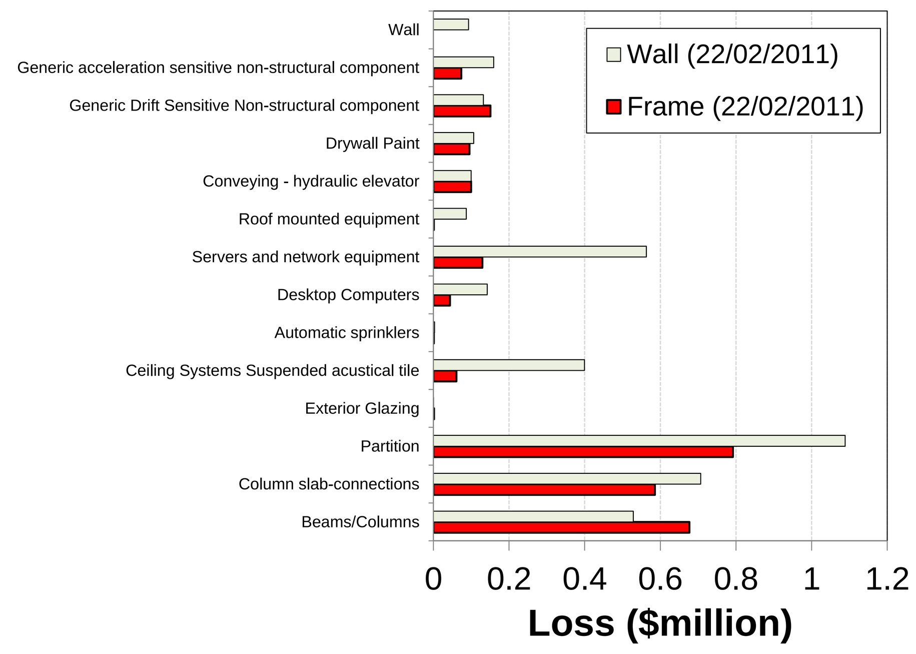




INDIVIDUAL BUILDING COMPONENT LOSSES

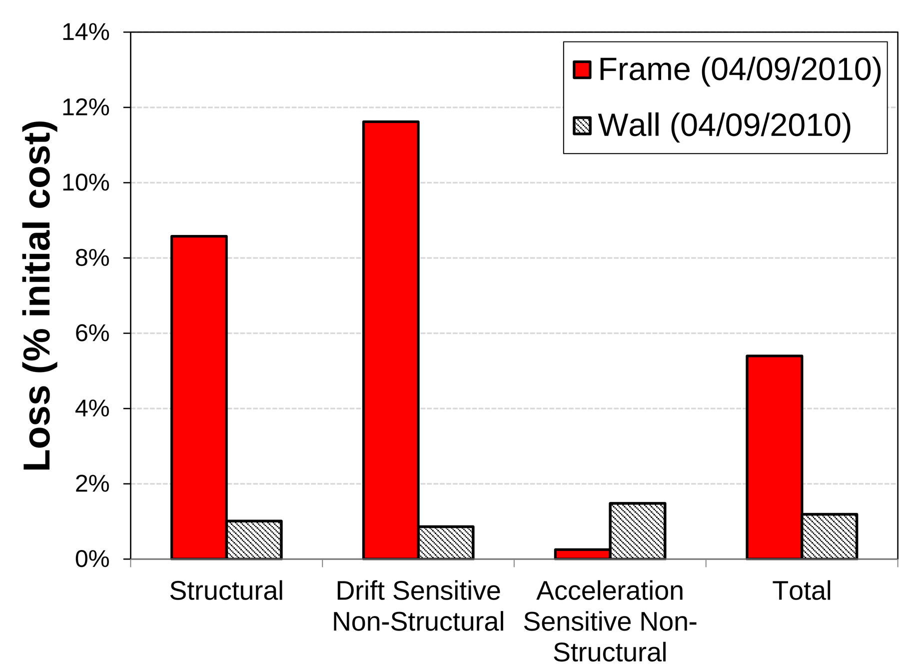
The figures below show losses by building component. It may be interesting to note that although the frame structure has much larger interstorey drifts at the bottom half of the structure compared to the wall structure in the 22/02/2011 event, the wall's interstorey drift continued to increase with height while the frame's interstorey drift decreases. This results in higher partition and column slab connections losses for the wall structure overall.

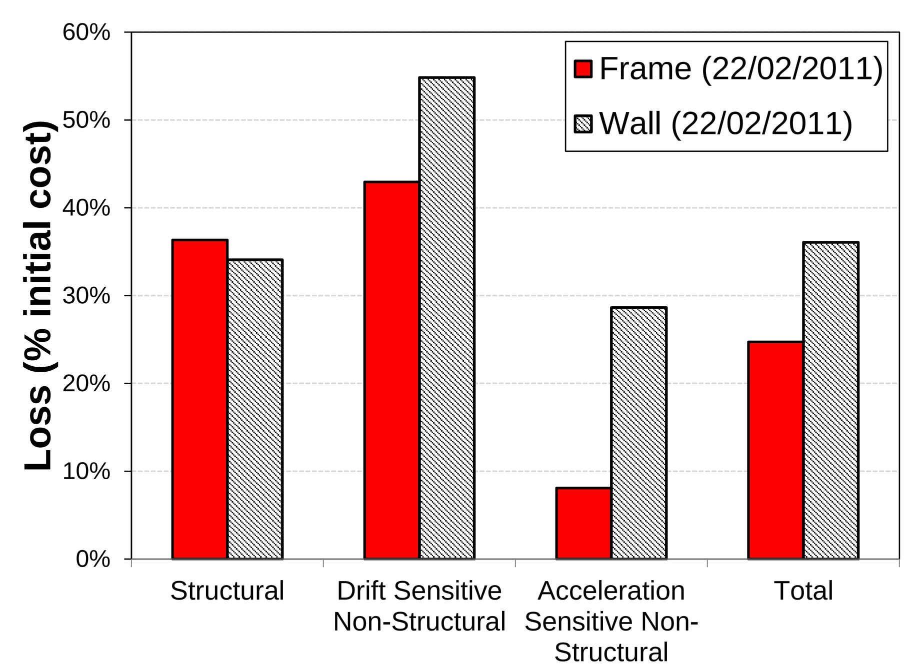




BUILDING LOSSES FOR COMPONENT GROUPS

The figures below show the loss from the three building component groups (structural drift sensitive, non-structural drift sensitive and non-structural acceleration sensitive components) as a percentage of the initial cost of each building content type. It can be seen that, while the wall performed well in the 04/09/2010 event compared to the frame structure, the opposite occurs in the 22/02/2011 event, with a total loss of 36% of the total building cost of the wall structure compared to 27% for the cheaper frame structure.





CONCLUSIONS

This preliminary study, illustrating a scenario loss comparison for a wall and frame type structure during earthquake shaking with two different shaking intensities, has shown that the structure with the minimum scenario loss can depend on the shaking intensity level.

Further studies, considering residual displacements and losses due to casualties/injuries and downtime effects, are required to quantify which system is the most seismically sustainable.

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